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None

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B6F

(54) **Generating droplets by heating**

(57) Generating droplets by heating a liquid jet recorder having an electro-thermal energy transducer used to heat liquid upon application of an electrical signal to form a flying droplet has a discharge signal generating unit for causing the electro-thermal energy transducer to discharge the droplet; and a heating signal generating unit for generating a high frequency electrical signal to be applied to said electro-thermal energy transducer within a range insufficient for discharging of the droplet. If the recorder has not been used for a first time period, the heating signal not causing droplet ejection is applied to condition the ink. If the recorder has not been used for a second, longer, period, droplets are also discharged but not used for printing, thus ejecting ink whose composition may have changed by evaporation.

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FIG. 1

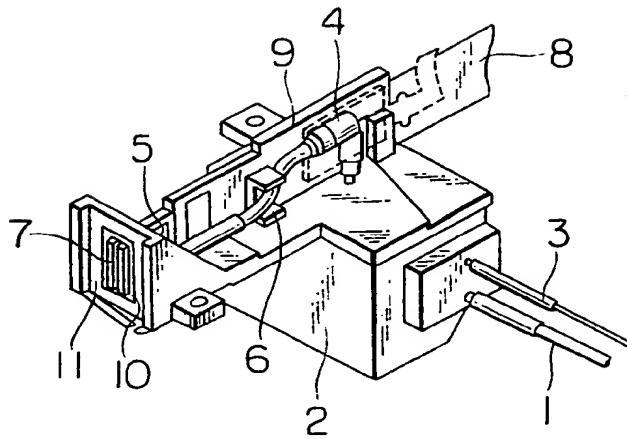


FIG. 2

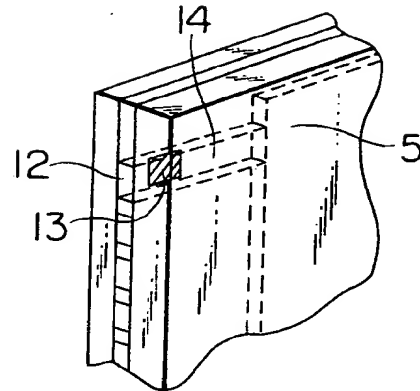


FIG. 3

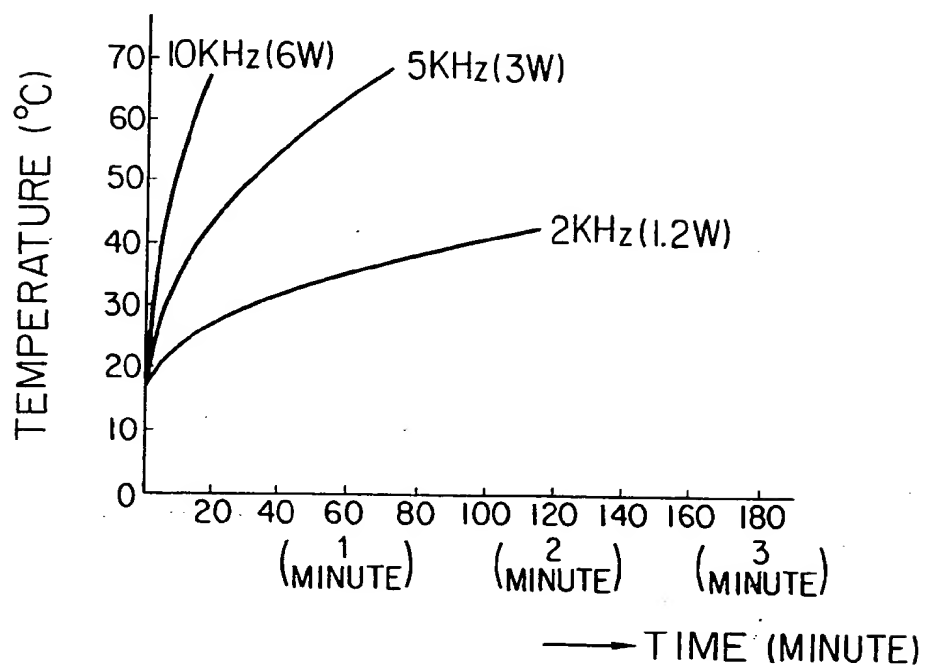


FIG. 4

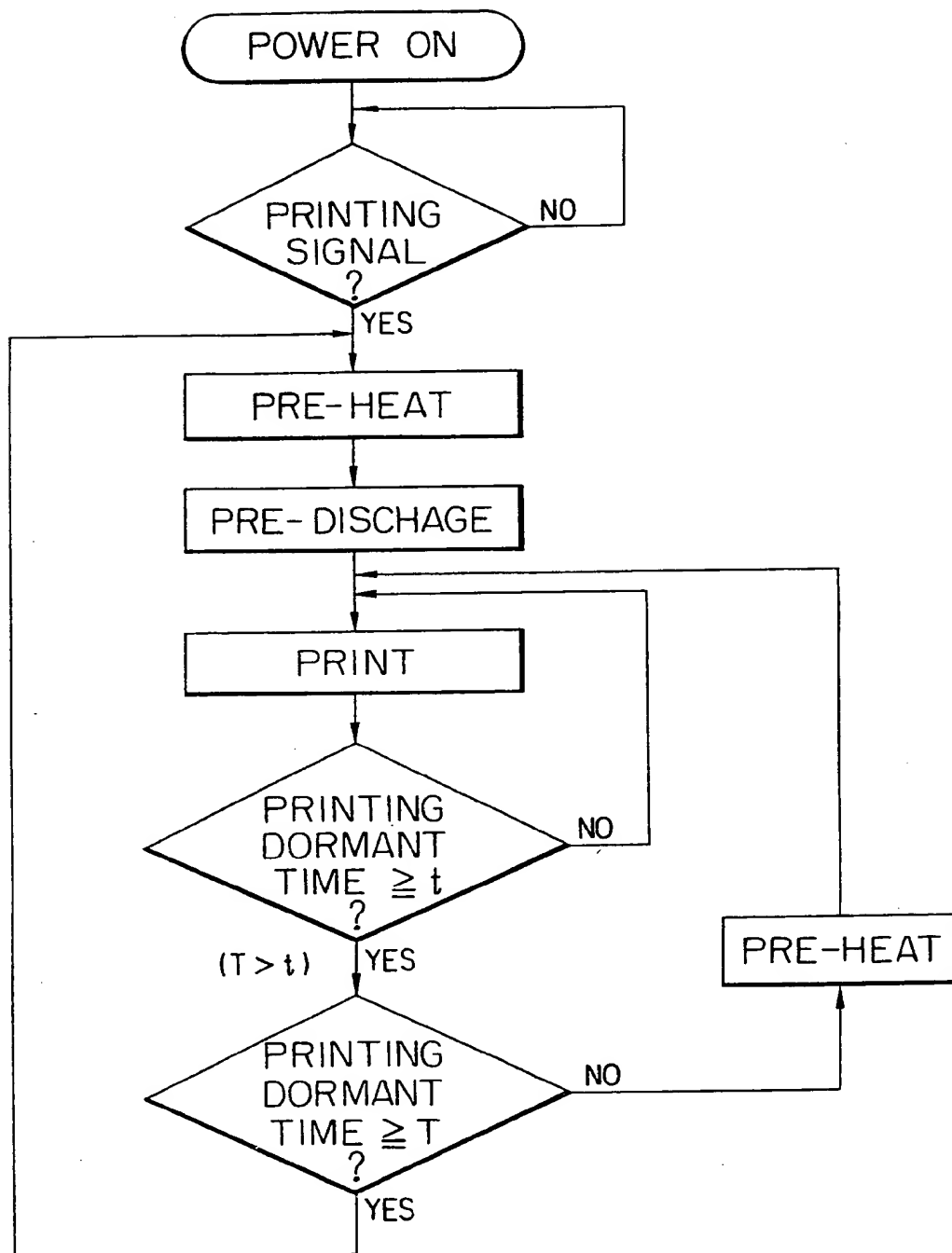
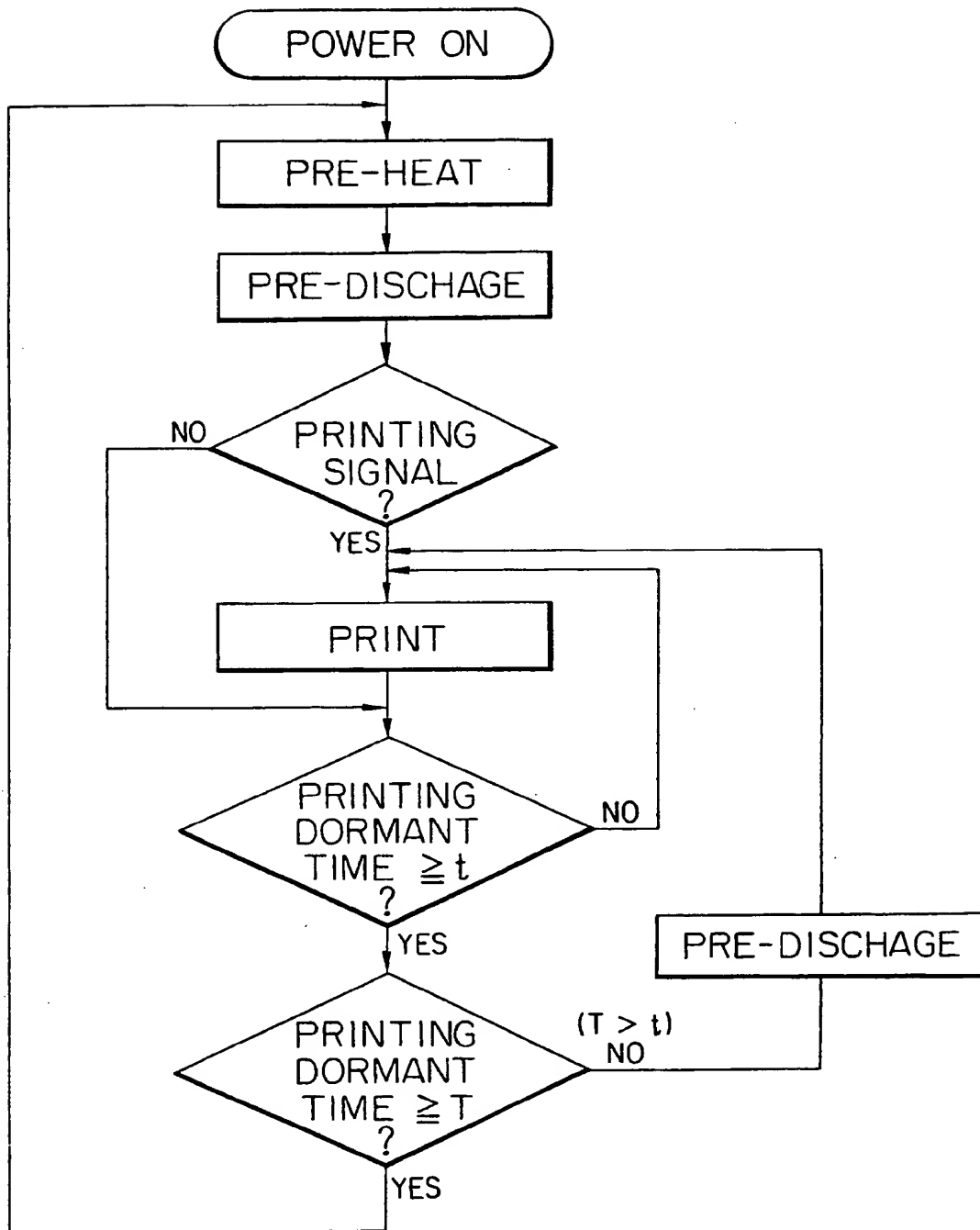


FIG. 5



SPECIFICATION

Liquid jet recorder and recording method

5 *Background of the Invention*

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Field of the Invention

The present invention relates to a liquid jet recorder which discharges liquid to form droplets and deposit the droplets on a record medium such as a paper to make a record, and more particularly to a liquid jet recorder and a recording method for imparting thermal energy to liquid to form droplets.

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Description of the Prior Art

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In a liquid jet recording method, droplets of recording liquid formed in one of various methods are deposited on a record medium such as a paper.

Among the recorders which employ such recording method, a liquid jet recorder which utilizes heat as an energy to form droplets has a structure suitable to a high density multi-orifice recording head.

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The liquid jet recorder which utilizes the heat as the droplet discharge energy comprises droplet forming means for forming the droplets of the recording liquid by heating the recording liquid to cause a rapid change in volume of the recording liquid to cause the liquid to be discharged from orifices, and a recording head having an electro-thermal energy transducer (heater) which is heated upon application of an electrical signal to heat the recording liquid.

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On the other hand, among the recording liquids used in the liquid jet recorders, aqueous recording liquid is preferable from standpoints of a recording characteristic and safety. The aqueous recording liquid consists of recording agent ingredient such as pigment or dye and solvent ingredient such as water or water and water soluble organic solvent for dissolving or dispersing the recording agent ingredient.

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In the recorder which utilizes the heat as the droplet discharge energy and the recorder which uses other droplet forming method, the orifices at the end of the nozzle from which the recording liquid is discharged are usually opened to the atmosphere externally of the recorder irrespective of the operation of the recorder.

As a result, if the non-record state lasts for a long time, water and other solvent such as volatile organic solvent are evaporated into the atmosphere through the orifices because the recording liquid is aqueous and the recording agent ingredient and non-volatile solvent remain in the recording liquid. Thus, the viscosity of the recording liquid increases beyond a range suitable for the discharge of the recording liquid. As a result, immediately after the record operation was resumed, the droplets are not discharged in spite of the application of a discharge signal and initial print portion of the recorded image includes a low quality print.

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In a known recording method, the recording liquid is always heated by applying to the heater an electrical signal of a level insufficient to cause the droplets to be discharged even when the droplet discharge signal is not applied so that the temperature of the recording liquid is always maintained in a predetermined range to assure good discharge condition of the droplets to the increase of viscosity of the recording liquid at a low temperature.

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For example, Japanese Patent Application Laid-Open No. 187364/1983 discloses a liquid jet recorder for forming flying droplets by heating liquid by an electro-thermal transducer and discharging the droplets to make a record. It includes detection means for detecting an external temperature and means for varying a duty cycle of a drive signal for pre-heating the electro-thermal transducer in accordance with the output from the detection means.

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In the recorder of this type, since the electrical signal is applied to the heater so that the recording liquid is always kept at a high temperature during a relatively long non-record or stop period, the solvent ingredient in the recording liquid is easily evaporated and the droplets are not discharged when the record operation is resumed. In addition, since the vicinity of the heater is always kept heated, the durability of the members around the heater is short or the recording liquid stored around the heater during the non-print period is modified by the heat and the color of the recording liquid changes or precipitate is generated in the recording liquid and it clogs the orifices.

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Summary of the Invention

It is an object of the present invention to provide a liquid jet recorder and a recording method for adjusting a viscosity of recording liquid within a range suitable for good droplet discharge condition and assuring good and stable droplet discharge condition when a record operation is resumed after a long non-print or stop period.

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It is another object of the present invention to provide a liquid jet recorder and a recording method for securing good and stable droplet discharge condition without reducing durability of members around a heater of the recorder and without modifying recording liquid stored around the heater during the non-print period by an affect of heat.

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It is other object of the present invention to provide a liquid jet recorder and a recording method which use a thermal energy to form droplets and assure good and stable droplet discharge condition by using droplet forming means as recording liquid heating means to adjust viscosity of the recording liquid.

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It is other object of the present invention to provide a liquid jet recorder having an electro-thermal energy transducer used to heat liquid upon application of an electrical signal to form flying droplets, including discharge signal generating means for causing the electro-thermal energy transducer to discharge droplets and heating signal generating means for generating a high frequency electrical signal to be applied to the electro-thermal energy transducer within a range insufficient for discharging of the droplets.

It is other object of the present invention to provide a recording method for making a record by applying an electrical signal to an electro-thermal energy transducer to heat liquid to form flying droplets, in which a high frequency electrical signal is applied from heating signal generating means to the electro-thermal energy transducer within a range insufficient for discharging of droplets if a next droplet is not discharged for more than a predetermined time period.

Brief Description of the Drawings

Figure 1 is a perspective view of a recording head of a liquid jet recorder of the present invention, *Figure 2* is a partial enlarged view of a vicinity of nozzle of the recording head shown in *Fig. 1*, *Figure 3* shows changes in time of temperature of heats generated when three different electrical signals are applied to the electro-thermal energy transducer, and *Figures 4 and 5* flow charts in a mechanism for controlling record operation of the present recorder.

Detailed Description of the Preferred Embodiments

The recorder of the present invention is explained with reference to a liquid jet recording head which utilizes heat as an energy to form droplets.

Fig. 1 is a perspective view of a recording head in the liquid jet recorder of the present invention and *Fig. 2* is a partial enlarged view of a vicinity of a nozzle of the recording head shown in *Fig. 1*.

Numeral 1 denotes a supply tube which connects a recording liquid main tank (not shown) and a sub-tank 2 for temporarily storing therein recording liquid in the recording head and supplies the recording liquid from the main tank to the sub-tank 2, numeral 3 denotes a suction tube connected to a recovery pump (not shown), numeral 4 denotes a supply pipe unit for supplying the recording liquid from the sub-tank 2 to a liquid chamber 5 numeral 6 denotes a retainer for the supply pipe unit 4, numeral 7 denotes a nozzle having a plurality of orifices 12 arranged longitudinally to discharge the recording liquid as shown in *Fig. 2*, numeral 8 denotes an electrical wiring unit including a flexible printed circuit board (FPC) for applying an electrical signal to a heater 13 to apply a thermal energy to the recording liquid in a liquid flow path 14 shown in *Fig. 2*, numeral 9 denotes a base plate on which the supply pipe unit 4, liquid chamber 5, nozzle 7, supply pipe retainer 6 and FPC 8 are mounted, numeral 10 denotes a bushing to support periphery of the nozzle and numeral 11 denotes a front plate.

In the present embodiment, droplet forming means for forming droplets is constructed by the orifices 12 and the liquid flow path 14 having a portion thereof connected to the orifices 12 and in which the heat from the heater is applied to the recording liquid, and liquid heating means is constructed by the heater 13 and the FPC 8 for applying the electrical signal to the heater 13 as required. While not shown in the drawing, the recorder includes discharge signal generating means for generating an electrical signal to discharge droplets and a heating signal generating means for generating a recording liquid heating electrical signal to be described later.

In order to make a record by the present recorder, the recording liquid is filled in to the sub-tank 2, the liquid chamber 5 and the liquid flow path 14 from the main tank through the supply tube 1 and the supply pipe unit 4. A recording signal is applied to the heater 13 through the FPC 8, that is, the electrical signal from the droplet discharge signal generating means is applied to the heater 13. As a result, the heater 13 generates a heat and a thermal energy is applied to the recording liquid in the liquid flow path 14 in the vicinity of the heater 13 and air bubbles are generated in the recording liquid due to momentary increase in volume of the recording liquid. Thus, the recording liquid downstream of the heater 13 is discharged from the orifices 12 and droplets of the recording liquid are formed. The droplets of the recording liquid are deposited on a record medium such as a paper fed in front of the nozzle 7 to make a record.

In the liquid jet recorder of the present invention, the recording liquid heating signal is applied to the heater 13 in the record operation, that is, immediately before the electrical signal is applied to the heater 13 to discharge the droplets for recording.

The recording liquid heating signal in the present record r serves to heat the recording liquid by the heater 13 to a temperature which assures a proper viscosity of the recording liquid to attain good recording liquid discharge condition, to an extent insufficient for discharging of the droplets. The signal is generated by the heating signal generating means.

The heating time of the recording liquid by the heater 13 heated by the application of the heating electrical signal is preferably as short as possible within a range in which the recording liquid is heated to the predetermined temperature.

By heating the recording medium in a short heating time, the heater 13 and the members around the heater are less affected by the heat leading to the degradation to extend the lifetime of those components. Further, the diffusion of the heat from the heater to the periphery of the heater is minimized and

the amount of recording liquid to be heated is reduced, the affect of the heat to the recording liquid in the liquid flow path or the liquid chamber is eliminated and the promotion of the evaporation of the solvent ingredient of the recording liquid from the orifices by long time heating is prevented. The heating time of the recording liquid is determined depending on a temperature characteristic of the recording liquid such as a heat capacity, a structure of the recorder and a temperature suitable to the recording liquid to be discharged.

Taking the above requirements into consideration, when the heating electrical signal is applied to the liquid jet recorder of the present invention, voltage, frequency and pulse width of the signal are selected in accordance with a condition of application of the droplet discharge signal, a temperature characteristic of the recording liquid used, a temperature characteristic of the viscosity of the recording liquid and a change of viscosity of the recording liquid in a non-print or stop period.

There are various methods to control the electrical signal to produce the heating electrical signal. In a method which uses an electrical signal circuit incorporated in the recorder, the discharge signal generating means is shared by the heating electrical signal generating means and the electrical signal from the discharge signal generating means is tailored in the following manner to produce the heating electrical signal.

A relation between the frequency, voltage and pulse width of the applied electrical signal and the heating temperature is shown in Fig. 3 in which electrical signals have voltage of 23.5 volts, pulse width of 5 μ s and frequencies of 10 KHz, 5 KHz and 2 KHz, respectively, are applied to the heater.

In order to achieve the above object,

- a) the pulse width of the droplet discharge signal is reduced and the frequency is increased,
- b) the voltage of the droplet discharge signal is reduced and the frequency is increased, or
- c) the pulse width and the voltage of the droplet discharge signal are reduced and the frequency is increased.

Particular values in those methods vary with the properties of the recording liquid used and the characteristics of the recorder and are not uniformly defined. In the method a), the pulse width of the heating electrical signal is preferably $1/1.25 - 1/100$ and more preferably $1/2 - 1/20$ of the pulse width of the droplet discharge signal. The frequency of the heating electrical signal is preferably 2 - 100 times and more preferably 5 - 50 times as high as the frequency of the droplet discharge signal. In the method b), the voltage of the heating electrical signal is preferably $1/1.25 - 1/10$ and more preferably $1/1.4 - 1/2.4$ of the voltage of the droplet discharge signal, and the frequency of the heating electrical signal is preferably 2 - 100 times and more preferably 5 - 50 times as high as the frequency of the droplet discharge signal. In the method c), the voltage of the heating electrical signal is preferably $1/1.25 - 1/10$ and more preferably $1/1.4 - 1/2.4$ of the voltage of the droplet discharge signal, the pulse width of the heating electrical signal is preferably $1/1.25 - 1/100$ and more preferably $1/2 - 1/20$ of the pulse width of the droplet discharge signal, and the frequency of the heating electrical signal is preferably 2 - 100 times and more preferably 5 - 50 times as high as the frequency of the droplet discharge signal.

The droplet discharge signal generating means and the heating electrical signal generating means may be independently and separately provided.

The heating electrical signal may be applied immediately before the droplet discharge signal is applied to the heater, or may be applied immediately before the droplet discharge signal is applied after the non-print period with the recorder being powered on or stop period with the recorder being powered off.

If the viscosity of the recording liquid in the liquid flow path is possibly not within the suitable range under the environment of use of the recorder such as temperature, the heating electrical signal is applied immediately before the droplet discharge signal is applied to the heater so that the viscosity of the recording liquid at the time of discharge is adjusted to a proper value. When the viscosity of the recording liquid is kept in the proper range under the environment of use of the recorder such as temperature but the next droplet is not discharged for a predetermined period (non-print mode) or the recorder is in a stop mode, the viscosity of the recording liquid may increase by the evaporation of the solvent into the atmosphere. Thus, the non-print or stop period is counted and if the record operation is resumed after more than the predetermined length of non-print or stop period, the heating electrical signal is applied to the heater.

The above predetermined length of the non-print or stop period, that is, the time period in which the viscosity of the recording liquid in the liquid flow path, particularly around the orifices goes beyond the preferable range depends on the characteristics of the recorder, the properties of the recording liquid and the environment conditions such as temperature and humidity of the location at which the recorder is installed. Accordingly, it is determined in accordance with a particular recorder and the operation condition thereof.

In the recorder of the present invention, after the heating electrical signal was applied to the heater, non-print droplet discharge signal may be applied to the heater and then the print droplet discharge signal may be applied to the heater.

In the recorder of the present invention, the non-print droplet discharge signal causes the droplet to be discharged but the droplet is recovered by the recorder and not used for printing on the record medium.

By applying the non-print droplet discharge signal to the heater after the heating electrical signal was applied to the heater, even if the non-print period or the stop period is very long and the viscosity of the

recording liquid increases by the evaporation of the solvent, the heater is heated by the heating electrical signal and the high viscosity recording liquid is heated and the temperature thereof rises. As a result, the viscosity of the recording liquid is lowered to an extent to enable discharging of the droplet although the droplet formed may not be good. Then, as the droplet discharge signal is applied to the heater, the recording liquid near the heater is discharged out of the liquid flow path and the recording liquid having the viscosity which is within the suitable range for discharging is supplied to the vicinity of the heater. The good discharge condition of the recording liquid is thereafter maintained.

The non-print droplet discharge signal is applied under the condition that the recording liquid having the viscosity which is beyond the suitable range for discharging is discharged by the application of the heating electrical signal to the heater and the discharged droplet is removed from the liquid flow path.

Figs. 4 and 5 show flow charts in a control unit for the recorder of the present invention. In Figs. 4 and 5, t indicates an upper limit of the non-print time in which pre-heating is not required, that is, the operation to apply the heating electrical signal to heat the recording liquid to the extent that the recording liquid is not discharged is not required, and T indicates an upper limit of the non-print time in which pre-heating is required. After the time period T , the pre-heating and pre-discharging are required. The pre-discharging means the non-print droplet discharging.

In the control unit shown in Fig. 4, when a print signal or the print droplet discharge signal is applied after power-on, the pre-heating and the pre-discharging are conducted in this order before the print droplet is discharged. Then, the discharge signal generating means generates the discharge electrical signal which is applied to the heater to discharge the recording liquid. If the non-print time exceeds t , the pre-heating is effected, and if the non-print time exceeds T , the pre-heating and the pre-discharging are effected.

In the control unit shown in Fig. 5, when the power is turned on, the pre-heating and the pre-discharging are effected, and if the printing is not effected after the power-on, the non-print time is counted and if it exceeds t , the pre-heating is effected. If it exceeds T , the pre-heating and the pre-discharging are effected. The control for the non-print period after printing is similar to that of Fig. 4.

In the recorder of the present invention described above, the thermal energy is utilized to form the droplet and the discharge energy generating means (heater) is shared by the means for heating the recording liquid to the extent that it is not discharged. These means may be separately and independently provided or where the heat is not used to form the droplet, recording liquid heating means such as a heater may be provided to carry out the control described above.

In the liquid jet recorder of the present invention described above, the recording liquid heating signal and, if necessary, the non-print droplet discharge electrical signal are applied to the heater 13 immediately before the droplet discharge electrical signal is applied so that the viscosity of the recording liquid to be discharged is adjusted to a range suitable to obtain good droplet discharge condition. Thus, even if the record operation is resumed after a long non-print or stop period, the good and stable droplet discharge condition is always attained.

Since the recording liquid is not frequently heated by the recording liquid heating signal and the heating time is very short, the durability of the member around the heater of the recorder is not lowered by the affect of the heat and the recording liquid stored in the vicinity of the heater during the non-print period is not modified by the heat and the good and stable droplet discharge condition is attained.

In the present recorder which utilizes the thermal energy to form the droplet, the recording liquid heating means for primarily adjusting the viscosity of the recording liquid is shared by the droplet forming means. Accordingly, no separate recording liquid heating means is required and the good and stable droplet discharge condition is always attained.

Example 1

In the liquid jet recorder of the present invention having the recording head as shown in Fig. 1 in which 24 orifices (having size of $50 \times 40 \mu\text{m}$) are arranged in a vertical line at a pitch of 0.141 mm, the recording liquid having the following composition is filled, and after 1-hour non-print period under 25 °C and 30% RH, the print operation is resumed by applying a heating electrical signal having a voltage of 23.5 V, a pulse width of 5 μs and a frequency of 10 KHz to the heater immediately before a droplet discharge electrical signal having a voltage of 23.5 V, a pulse width of 10 μs and a frequency of 2 KHz is applied. The number of non-discharged droplets to the print signals is counted until all of the 24 orifices discharge the print droplets to evaluate the recorder for the non-discharging of the droplets after the non-print period. The result is shown in Table 1.

The composition of the recording liquid used is shown below.

[Composition of the recording liquid]

60	C.I. Direct black 19	2 weight parts	60
	Diethylene glycol	30 weight parts	
	Water	70 weight parts	

Comparative Example 1

In a recorder having a construction similar to that of the Example 1 but only the print droplet electrical signal is applied to the heater, the recording liquid used in the Example 1 is filled, and after 1-hour non-print time under 25 °C and 30% RH, the record operation is resumed by applying the droplet discharge electrical signal having a voltage of 23.5 V, a pulse width of 10 μ s and a frequency of 2 KHz to the heater. The recorder is evaluated for the non-discharging after the non-print period as was done in the Example 1. The result is shown in Table 1.

Example 2

The recorder used in the Example 1 is used. The non-print period is 12 hours. After the heating electrical signal was applied, the droplet discharge electrical signal comprising 100 pulses is applied to the heater to discharge the non-print droplets. Then, the print droplet discharge electrical signal is applied to the heater. The other steps are equal to those of the Example 1. The recording liquid used in the Example 1 is used and the recorder is evaluated in the same manner as the Example 1. The result is shown in Table 1.

Comparative Example 2

Except for the non-print time of 12 hours, the record is made in the same manner as the comparative Example 1 and the evaluation is done in the same manner as the Example 1. The result is shown in Table 1.

TABLE 1

		Number of non-discharged droplets counted until all of 24 orifices discharge droplets	Non-print time (hour)	
25				25
30	Example 1	0	1	30
	Example 2	0	12	
	Comparative Example 1	1000	1	
	Comparative Example 2	Two of 24 orifices do not discharge droplets	12	35

CLAIMS

1. A liquid jet recorder having an electro-thermal energy transducer used to heat liquid upon application of an electrical signal to form a flying droplet, comprising: discharge signal generating means for causing said electro-thermal energy transducer to discharge the droplet; and heating signal generating means for generating a high frequency electrical signal to be applied to said electro-thermal energy transducer within a range insufficient for discharging of the droplet.
2. A liquid jet recorder according to Claim 1 wherein said discharge signal generating means and said heating signal generating means are common.
3. A liquid jet recorder according to Claim 1 wherein said discharge signal generating means and said heating signal generating means are separate from each other.
4. A liquid jet recorder according to Claim 1 wherein a pulse width of said high frequency electrical signal is 1/1.25 to 1/100 of a pulse width of the droplet discharge signal.
5. A liquid jet recorder according to Claim 1 wherein a voltage of said high frequency electrical signal is 1/1.25 to 1/10 of a voltage of the droplet discharge signal.
6. A liquid jet recorder according to Claim 1 wherein a frequency of said high frequency electrical signal is 2 to 100 times as high as frequency of the droplet discharge signal.
7. A recording method for making a record by applying an electrical signal to an electro-thermal energy transducer to heat liquid to form a flying droplet, characterized by that a high frequency electrical signal of a level insufficient for discharging of the droplet is applied to said electro-thermal energy transducer by heating signal generating means when a next droplet is not discharged for more than a predetermined time period.
8. A recording method according to Claim 7 wherein non-print droplet is discharged after said high frequency electrical signal was applied.
9. A recording method according to Claim 8 wherein said non-print droplet is discharged a predetermined time after said predetermined time period.

10. A recording method according to Claim 7 wherein said discharge signal generating means and said heating signal generating means are common.
11. A recording method according to Claim 7 wherein said discharge signal generating means and said heating signal generating means are separate from each other.
- 5 12. A recording method according to Claim 1 wherein a pulse width of said high frequency electrical signal is $1/1.25$ to $1/100$ of a pulse width of the droplet discharge signal. 5
13. A recording method according to Claim 7 wherein a voltage of said high frequency electrical signal is $1/1.25$ to $1/10$ of a voltage of the droplet discharge signal.
14. A recording method according to Claim 7 wherein a frequency of said high frequency electrical 10 signal is 2 to 100 times as high as a frequency of the droplet discharge signal. 10
15. A recording method substantially as herein described with reference to the accompanying drawings.
16. A liquid jet recording device substantially as herein described with reference to the accompanying drawings.

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FIG. 1

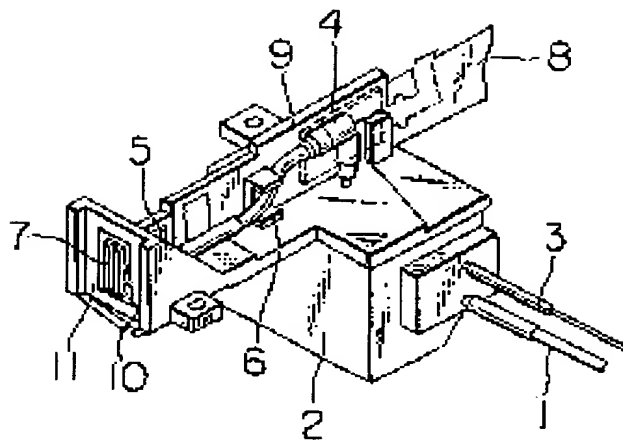


FIG. 2

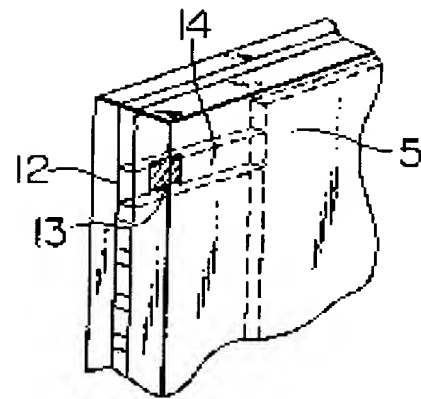


FIG. 3

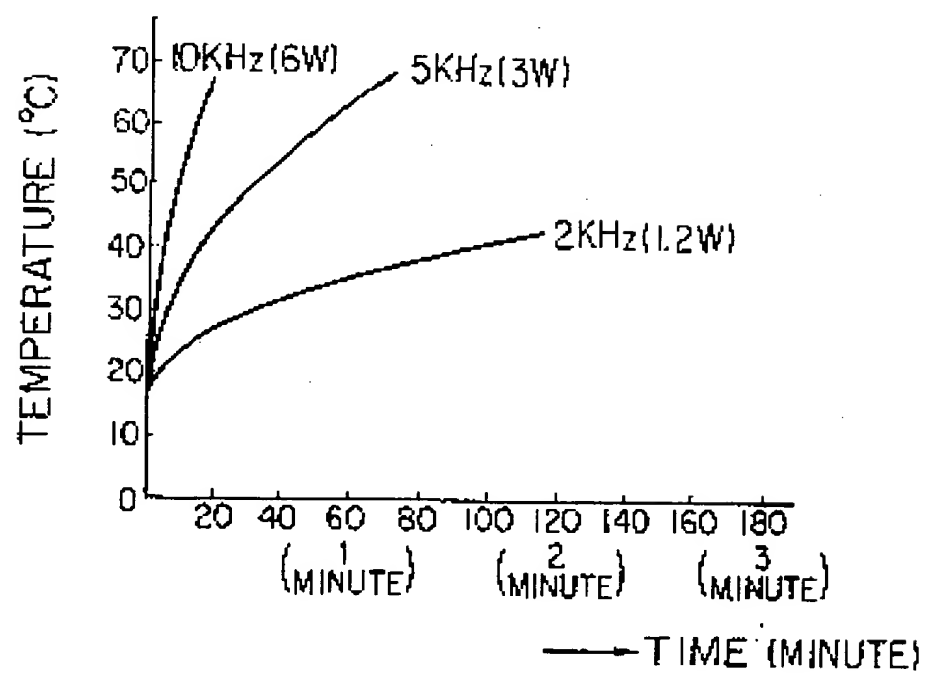


FIG. 4

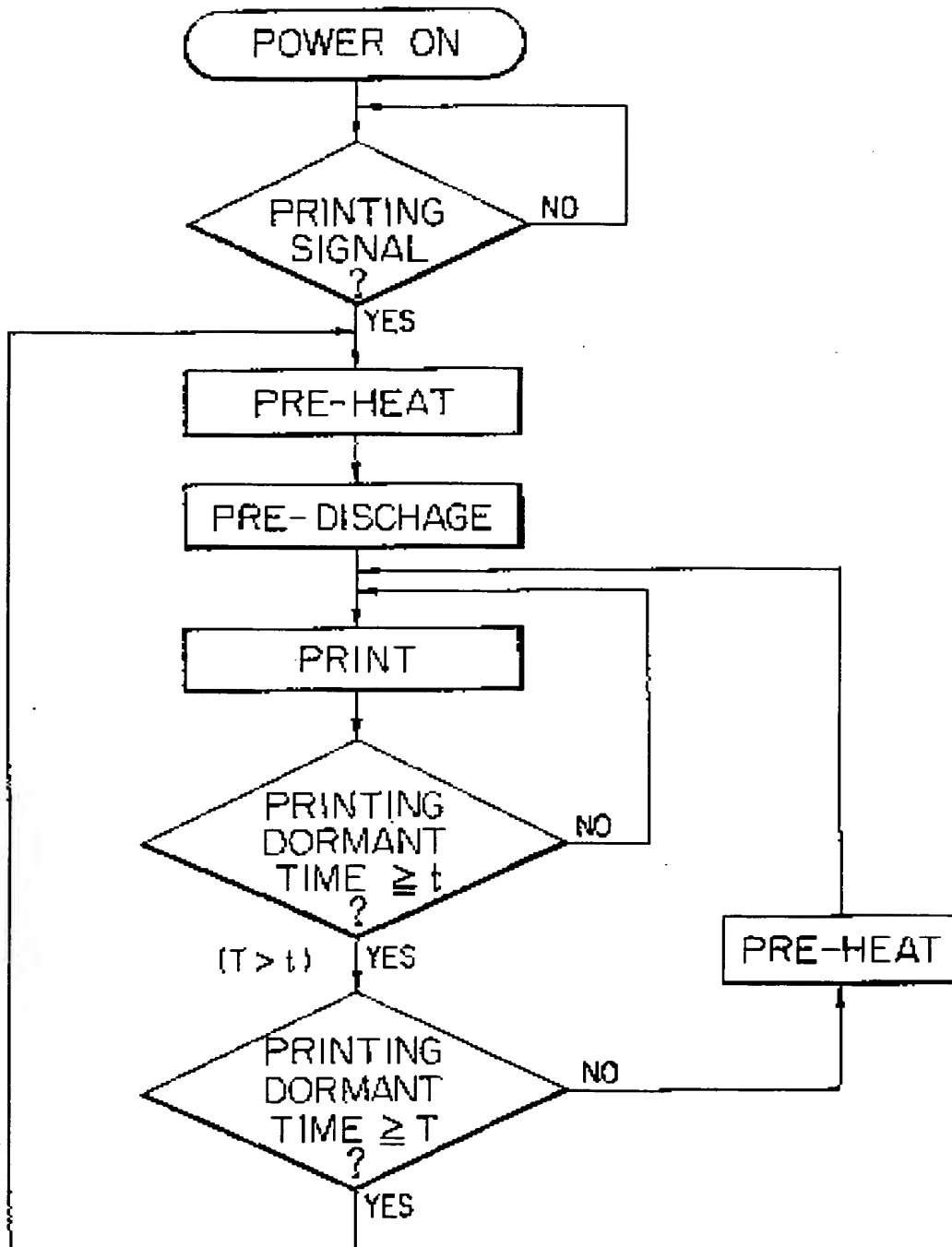
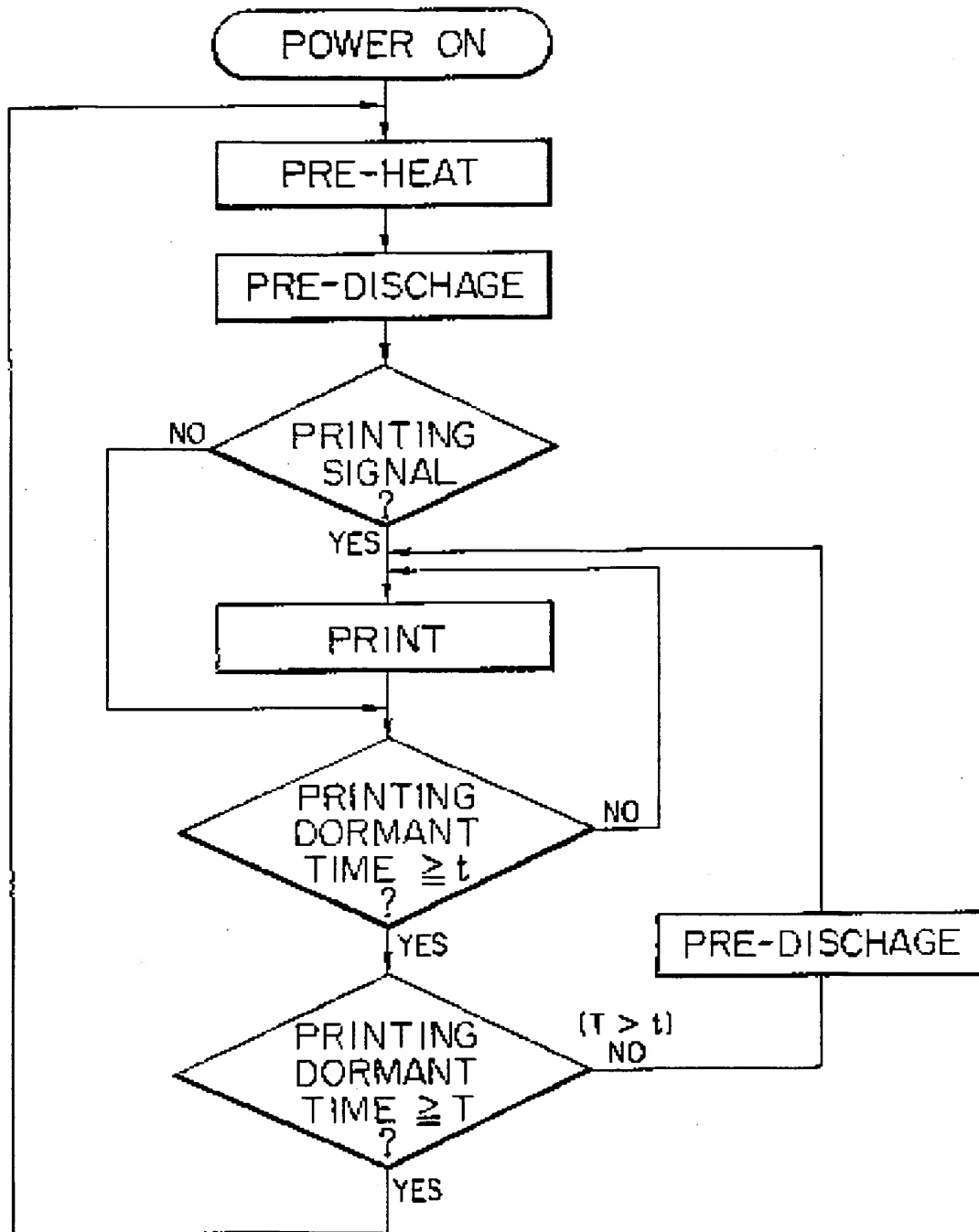


FIG. 5



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